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On the Optimality of U.S. Fiscal Policy: 1960- 2010*

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Abstract

This paper assesses the optimality of U.S. fiscal policy from 1960 to 2010. With this purpose, we present a tractable neoclassical economy with a benevolent government and characterize time-consistent, optimal fiscal policy. We then compare the model's prescriptions for income tax rates and government expenditure with their empirical counterparts observed in the U.S. in this period. We find that U.S. income taxation and government consumption expenditure were in line with the model's prescriptions from 1960 to 2000. However, starting in the early 2000s and for the rest of the decade, U.S. fiscal policy trended in a direction opposite to that of the optimal policy prescribed by the model. In particular, U.S. income tax rates declined below their optimal rates, and government consumption expenditures as a share of GDP sharply increased above their optimal levels. By way of example, while our model prescribes a 10% reduction in the government consumption expenditure-to-GDP ratio between 2001 and 2010, the U.S. ratio increased by 23% in this period.

JEL Codes: E62, H24, H40, H50

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I. Introduction

Measures of U.S. income tax rates and government consumption expenditure show significant variation in these two variables over the period from 1960 to 2010. In particular, a measure of synthetic income tax rates that includes personal current taxation, corporate income taxation and contributions to government social insurance allow us to distinguish two markedly different periods. In the first period, between 1960 and 2000, income tax rates display an upward trend, increasing the tax rate from 17% in the early 1960s to 23% in the late 1990s. In the second period, from the early 2000s to 2010, income tax rates decline for most of the decade, reversing the increases of the first period. The evolution of government consumption expenditure as a share of adjusted GDP, on the other hand, shows: (i) An increase during the decade of the 1960s; (ii) a downward trend from the early 1970s to the late 1990s, which reduced the government consumption-to-GDP ratio from 19.5% in 1970 to 15% in 2000; and finally (iii) a sharp increase in the 2000s, to reach a ratio of 18.5% in 2010.

In this paper, we assess quantitatively the optimality of income taxation and government consumption expenditures in the U.S. from 1960 to 2010. For this purpose, we present a tractable model that builds on normative neoclassical theory of public finance (see Kenneth L. Judd 1985 and Christophe Chamley 1986 for early contributions). In this theory, fiscal policy is set by a benevolent government that has full commitment to its policy choices, and that seeks to maximize households' lifetime utility. A well-known result that emerges from this theory is that the government should set confiscatory tax rates on capital income in the short run, and accumulate enough assets so that it will not need to rely on distortionary taxes in the long run. In this paper, we relax the assumption of full commitment and study optimal income taxation and government expenditures when the government lacks any form of commitment to its policy. To characterize time-consistent, optimal fiscal policy, we focus on Markov-perfect equilibria, where households' and the government's policy rules are functions of payoff-relevant variables only (see Paul Klein, Per Krusell and José V. Ríos-Rull 2006, Salvador Ortigueira 2006, and Fernando M. Martin 2009 for early analyses of Markov-perfect optimal policy).

Our analytical framework to obtain optimal fiscal policy, against which U.S. policy is then compared and assessed, is the standard neoclassical model of capital accumulation. Infinitely-lived households make consumption/savigns decisions, supply labor to firms and pay direct and indirect taxes to the government. Firms produce an homogeneous good that can be either consumed or used as an input in the production of physical capital. However, instead of the linear adjustment technology for converting the homogeneous good into the capital good, we assume a convex adjustment technology as in Robert E. Lucas and Edward C. Prescott (1971). In addition to rendering the price of capital endogenous, this convex technology allows us to obtain a characterization of Markov-perfect equilibria in closed form. The benevolent government chooses fiscal policy, consisting of a level of expenditure in a public good, income taxation and debt issues. For simplicity, we assume that consumption and investment taxes and transfers to households are exogenous. The lack of commitment forces the government to make and carry out policy decisions sequentially, and to form expectations on its future decisions and on those of the households when setting current policy. From the Markov-perfect equilibria of this model we establish a unique relationship between households' consumption expenditure and optimal fiscal policy (i.e., income taxation and government consumption expenditure). We use this relationship to generate equilibrium paths for optimal policy by conditioning on the observed values of households' consumption expenditure in the U.S. from 1960 to 2010.

To construct the empirical counterparts of the fiscal policy variables in our theory, we use annual data from the National Income and Product Accounts (NIPA) of the Bureau of Economic Analysis. In particular, we construct tax rates on consumption and investment, income tax rates and the government consumption expenditure-to-GDP ratio from 1960 to 2010. When these variables are compared with their respective optimal values generated from the model, we obtain the following findings. During the forty-year period between 1960 and 2000, actual and optimal policies are fairly close to each other. When actual and optimal income tax rates are compared, both trend upward during this period. Although for a few years in the 1970s and the 1990s there is a gap between the two rates of almost four percentage points, for most years, especially in the 1980s, the two series are very close to each other. Similarly, actual and optimal government consumption expenditure-to-GDP ratios move closely together during this forty-year period. The two ratios increase during the 1960s and then decrease from 1970 to 2000. However, our findings are strikingly different for the ten-year period between 2001 and 2010. Actual income tax rates begin to decline in the early 2000s, whereas optimal rates continue to display an upward trend, thus creating an increasing gap between actual and optimal tax rates. Actual and optimal government consumption expenditure-to-GDP ratios also follow opposite trends during the decade of the 2000s. Actual ratios shoot up in the early 2000s and continue to increase during the decade. In contrast, optimal ratios continue to display a downward trend, giving rise to an increasing gap between the two. In sum, when our model is fed with the U.S. values for households' consumption expenditure, it offers a clear assessment of the optimality of U.S. income tax rates and government consumption expenditure-to-GDP ratios. From 1960 to 2000 U.S. policy is close to that prescribed by the model, and it can accordingly be considered optimal. However, from 2001 to 2010 U.S. policy departs from the model's prescriptions and it is then deemed non optimal.

The remainder of the paper is organized as follows. Section II outlines our model economy. Section III presents the maximization problems solved by the households and by the government. Then, it defines and characterizes Markov-perfect equilibria, which form our benchmark to assess the optimality of U.S. fiscal policy. In Section IV we construct tax rates on consumption, tax rates on investment, income tax rates and the government consumption expenditure-to-GDP ratio of the U.S. economy from 1960 to 2010. In Section V we calibrate our model, generate optimal fiscal policy in Markov-perfect equilibrium and then compare this optimal policy with U.S. policy. Section VI presents our concluding remarks. An Appendix contains the proof of our Proposition which characterizes Markov-perfect optimal fiscal policy.

II. A Simple Model of Optimal Fiscal Policy

We present a simple model to characterize optimal fiscal policy under no commitment. Our framework is a standard two-sector model of capital accumulation with a representative household. A benevolent government provides a valued public good and makes transfers to households. In order to finance the provision of the public good and the transfers, the government uses taxes and public debt. There are three taxes available: a consumption tax, an investment tax and a tax on households' income. We set the level of transfers and the tax rates on consumption and investment exogenously and let the government choose the level of expenditure in the public good, G_t, the tax rate on income, τ_t, and debt issues, B_{t+1}, which mature in period $t+1$.

We begin by describing the objective and the restrictions faced by each agent in this economy. We then characterize optimal fiscal policy in Markov-perfect equilibrium.

A. *Production*

There are two sectors of production. One sector produces an homogeneous good which is consumed by the households as a private good, C_t, used as an input in the sector that produces the capital good, X_t, and consumed by the households as a government-provided public good, G_t. Production of the homogeneous good is described by the Cobb-Douglas production function

$$C_t + X_t + G_t = AK_t^{\alpha}. \tag{1}$$

The other sector produces the capital good. Production of the capital good is described by

Cobb-Douglas production function

$$K_{t+1} = DX_t^{\lambda} K_t^{1-\lambda}, \tag{2}$$

where $D > 0$ and $0 \leq \lambda \leq 1$ are parameters.[1] Both sectors are assumed to be competitive. From this two-sector production representation it is straightforward to see that the producer price of the capital good in terms of the homogeneous good, p_t, is given by

$$p_t = \left(\lambda D X_t^{\lambda-1} K_t^{1-\lambda}\right)^{-1}. \tag{3}$$

The demand of physical capital is given by

$$r_t = \alpha A K_t^{\alpha-1} + p_t(1-\lambda) D X_t^{\lambda} K_t^{-\lambda}, \tag{4}$$

where r_t is the rental price of physical capital in units of the homogeneous good. From the zero-profit condition we get the wage as

$$\omega_t = (1-\alpha) A K_t^{\alpha}. \tag{5}$$

The capital production technology (2) nests three different specifications depending on the values of D and λ: *(i)* A fixed capital stock, $D = 1$ and $\lambda = 0$; *(ii)* full capital depreciation, $\lambda = 1$; and *(iii)* partial capital depreciation with investment adjustment costs, $0 < \lambda < 1$. We will focus on this latter specification where the decreasing returns to investment can be viewed as stemming from adjustment costs. Indeed, in this case the capital production technology in (2) is equivalent, up to a second order approximation, to the commonly-used law of motion for capital under quadratic adjustment costs

$$K_{t+1} = (1-\delta)K_t + X_t - \frac{\chi}{2}\left(\frac{X_t}{K_t} - \delta\right)^2 K_t, \tag{6}$$

when

$$\delta = \lambda, \;\; \chi = (1-\lambda)/\lambda \text{ and } D = \lambda^{-\lambda}. \tag{7}$$

While our use of production technology (2) is motivated by analytical tractability, we will exploit this equivalence to calibrate our model economy.

[1] This log-linear technology is a particular case of the law of motion for physical capital assumed by Lucas and Prescott (1971). It has been used by Zvi Hercowitz and Michael Sampson (1991) to study business cycles in a model of endogenous growth. Abel (2003) embeds this technology into an overlapping generations model to assess the effects of a baby boom on stock prices and capital accumulation. More recently, Jin (2012) adopts this technology in his analysis of trade and international capital flows.

B. *Households*

There is a continuum of homogeneous households with measure one. Each household chooses consumption and savings in order to maximize lifetime utility. Households' preferences are given by

$$\sum_{t=0}^{\infty} \beta^t (\ln c_t + \theta \ln G_t) \text{ with } \theta > 0, \tag{8}$$

where c_t denotes consumption of the private good and G_t is household consumption of the government-provided public good.

Households' asset holdings are made up of physical capital, k_t, which is rented to firms at the rate r_t, and government bonds, b_t. The period budget constraint faced by a household is

$$(1 + \tau_{c,t})c_t + (1 + \tau_{x,t})p_t k_{t+1} + q_t b_{t+1} = b_t + (1 - \tau_t)[w_t + r_t k_t] + T_t, \tag{9}$$

where $\tau_{c,t}$ and $\tau_{x,t}$ are the tax rates on consumption and investment, respectively. T_t denotes the transfers received from the government. Household income is taxed at the rate τ_t. We assume that neither income earned on public debt nor transfers are subject to taxation.

C. *Government*

The fiscal authority chooses the level of expenditure on the public good and its financing through income taxes and debt. As indicated above, transfers to households and taxes on consumption and investment are exogenously determined and thus are not part of the fiscal authority's decision problem.

The fiscal authority is benevolent, in the sense that it seeks to maximize households' lifetime utility, (8), subject to its own budget constraint, to the economy's resource constraint and to the expected household consumption decisions. The period budget constraint of the government is

$$G_t + T_t + B_t = q_t B_{t+1} + \tau_t(w_t + r_t K_t) + \tau_{c,t} C_t + \tau_{x,t} p_t K_{t+1}. \tag{10}$$

The right-hand side of equation (10) represents government revenues, which are made up of debt issues, $q_t B_{t+1}$, income taxation plus taxes on consumption and investment. The left-hand side is government's total expenditure, including the provision of the public good, transfers and the repayment of outstanding debt. In the next section we characterize optimal fiscal policy in the Markov-perfect equilibrium of this economy.

D. *Markov-perfect Optimal Fiscal Policy*

The government is assumed to lack any commitment to policy, which prevents it from credibly announcing taxes, expenditures in the public good and debt issues. To characterize time-consistent optimal policy we focus on Markov-perfect equilibria of this economy populated by a continuum of households and a government. The government acts sequentially, foreseeing its future behavior, and that of the households, when choosing current policy. Due to the government's lack of commitment, households and the period-t government make their respective decisions simultaneously within period. Hence, both agents must forecast not only future variables but also those that are being currently chosen by the other agents. We next present the maximization problem solved by each agent in turn.

E. *The Maximization Problem of a Typical Household*

The household chooses how much to consume and save and how to allocate savings between physical capital and public debt. In making these decisions, the household must foresee both current and future governments' fiscal policy.

The maximization problem of a household that holds physical assets k and government debt b is now presented. Household expectations on current and future policies are denoted as: *(i)* the tax rate on income is expected to be set as $\psi_\tau : (K \times B) \to \tau$, both in the current and in future periods; *(ii)* debt issues are expected to be set as $\psi_{B'} : (K \times B) \to B'$; *(iii)* government expenditure is expected to be set according to the policy $\psi_G : (K \times B) \to G$. Denoting the vector of aggregate state variables by $S \equiv (K, B)$, the maximization problem of the household is

$$v(k, b, S) = \max_{c,k',b'} \left\{ \ln c + \theta \ln \psi_G(S) + \beta \tilde{v}(k', b', S') \right\} \tag{11}$$

$$s.t.$$

$$(1+\tau_c)c + (1+\tau_x)p(S)k' + q(S)b' = b + (1 - \psi_\tau(S)) \left[w(S) + r(S)k \right] + T. \tag{12}$$

The function $\tilde{v}(k', b', S')$ on the right-hand side of the maximization problem in (11) is the continuation value as foreseen by the household. Note that $S' \equiv (K', B')$ is next period's vector of aggregate state variables as foreseen by the household, i.e., the economy-wide stock of physical capital is expected to evolve according to the law of motion $K' = \mathcal{H}(S)$ and debt issues are expected to be $B' = \psi_{B'}(S)$. In the budget constraint, $p(S)$, $q(S)$, $w(S)$ and $r(S)$ are pricing functions. The maximization problem above, along with the representative household assumption, $k = K$ and $b = B$, yields a consumption function, $C(S)$, that satisfies the following two functional equations

$$\frac{1}{(1+\tau_c)C(S)} = \beta\left[\frac{1}{(1+\tau_c')C(S')} \times \frac{(1-\psi_\tau(S'))r(S')}{(1+\tau_x)p(S)}\right] \tag{13}$$

and

$$\frac{q(S)}{(1+\tau_c)C(S)} = \beta\left[\frac{1}{(1+\tau_c')C(S')}\right]. \tag{14}$$

Equation (13) is the Euler equation and (14) is the standard pricing equation of a claim to one unit of consumption.

F. *The Maximization Problem of the Government*

The time-t government sets the income tax rate for the period, τ, debt issues, B', and the level of expenditure in the public good, G, foreseeing the fiscal policy to be set by successive governments and the household's consumption function. These fiscal policy decisions are taken to maximize the household's lifetime utility. The problem of the period-t government is then written as

$$V(S) = \max_{\tau,B',G}\left\{\ln C(S) + \theta \ln G + \beta\tilde{V}(S')\right\} \tag{15}$$

s.t.

$$C(S) + X + G = AK^\alpha \tag{16}$$

$$G + T + B = q(S)B' + \tau\left[w(S) + r(S)K\right] + \tau_c C(S) + \tau_x p(S)K' \tag{17}$$

$$K' = X^\lambda K^{1-\lambda} \tag{18}$$

and the pricing equations (3), (4), (5) and (14),

where $C(S)$ and $\tilde{V}(S')$ are, respectively, the household consumption function and the continuation value as foreseen by the time-t government. Restrictions $(16)-(18)$ are, respectively, the economy's resource constraint, the government budget constraint and the capital production technology. The fiscal policy that solves the government maximization problem must satisfy the following generalized Euler equations,

$$\frac{\theta}{G(S)}\frac{1}{\lambda D X(S)^{\lambda-1}K^{1-\lambda}} = \beta\left[\frac{C_K(S')}{C(S')} + \frac{\theta}{G(S')}\left(\alpha A(K')^{\alpha-1} - C_K(S') + \frac{1-\lambda}{\lambda}\frac{X(S')}{K'}\right)\right] \tag{19}$$

and

$$C_B(S')\left(\frac{1}{C(S')} - \frac{\theta}{G(S')}\right) = 0, \tag{20}$$

where C_K and C_B denote the derivatives of the consumption function, C, with respect to K and B, respectively.

Generalized Euler equation (19) establishes that the marginal value of taxation must equal the marginal value of investment in physical capital. Generalized Euler equation (20) is a no-arbitrage condition between taxation and debt, establishing that the government must be indifferent between using taxes or debt to finance the last unit of expenditure in the public good. In addition to these generalized Euler equations, fiscal policy must be sustainable, which in our setting implies that debt must be bounded in the long run.

G. *Markov-perfect Equilibrium*

We now formally define a Markov-perfect equilibrium in this economy.

DEFINITION: *A Markov-perfect equilibrium is a list of policy functions $C(K,B)$, $\psi_\tau(K,B)$, $\psi_{B'}(K,B)$ and $\psi_G(K,B)$; a continuation value function $\tilde{V}(K,B)$; and pricing functions $p(K,B)$, $q(K,B)$, $r(K,B)$ and $w(K)$ such that:*

(i) *Given ψ_τ, $\psi_{B'}$, ψ_G and the pricing functions, the function C solves the household's maximization problem.*

(ii) *Given C and $\tilde{V}$, functions ψ_τ, $\psi_{B'}$ and ψ_G solve the government's maximization problem.*

(iii) The pricing functions are given by (3), (4), (5) and (14)

(iv) *$\tilde{V}$ is the value function of the government, that is,*

$$\tilde{V}(K,B) = \ln C(K,B) + \theta \ln \psi_G(K,B) + \beta \tilde{V}[X(K,B)^\lambda K^{1-\lambda}, \psi_{B'}(K,B)],$$

where $X(K,B) = AK^\alpha - \psi_G(K,B) - C(K,B)$.

The next Proposition presents policy functions in a Markov-perfect equilibrium and shows the existence of a multiplicity of such equilibria.

PROPOSITION 1 *There exists a continuous multiplicity of Markov-perfect equilibria. In particular, any quadruplet of policy functions in the following family indexed by $a \in (0,1)$ conforms* *a Markov-perfect equilibrium of our model economy:*

$$C(K; a) = aAK^{\alpha} \tag{21}$$

$$\psi_{\tau}(K, B; a) = \frac{B}{\left[1 + \frac{1-\lambda}{\lambda} a_X(a)\right] AK^{\alpha}} + f \tag{22}$$

$$\psi_{B'}(K; a) = hD^{\alpha} a_X(a)^{\alpha\lambda} A^{1+\alpha\lambda} K^{(1-(1-\alpha)\lambda)\alpha} \tag{23}$$

$$\psi_G(K; a) = \frac{(1-a)\theta(1-\beta[1-(1-\alpha)\lambda])}{\theta[1-\beta(1-\lambda)] + \beta\alpha\lambda} AK^{\alpha}, \tag{24}$$

where f and h are functions of a and of the exogenous transfers and tax rates on consumption and investment. $a_X(a)$ is a function of a.

Functions f, h and $a_X(a)$, and the proof of the proposition are shown in the Appendix. Using these policy functions we now characterize income tax rates and government expenditure in the public good along the equilibrium path of a Markov-perfect equilibrium.

COROLLARY 2 *Along the equilibrium path of a Markov-perfect equilibrium, income tax rates, $\{\tau_t\}$, and government expenditure in the public good as a share of GDP, $\{g_t\}$, are given, respectively, by*

$$\tau_t = 1 - \frac{(1+\tau_{c,t})(1+\tau_{x,t-1})a_X(a)}{\beta(1+\tau_{c,t-1})[\alpha\lambda + (1-\lambda)a_X(a)]} \quad \textit{for} \quad t \geq 1 \tag{25}$$

$$g_t = \frac{a_G(a)}{1 + \frac{1-\lambda}{\lambda} a_X(a)} \quad \textit{for} \quad t \geq 0, \tag{26}$$

where $a_G(a)$ is a function of a which is shown in the Appendix. The income tax rate at $t = 0$ depends on initial conditions K_0 and B_0.

The proof of the Corollary is straightforward. Income tax rates are derived from evaluating (22) at (23) and at the stock of capital implied by the policy functions in the Proposition. Government expenditure as a share of GDP is obtained from dividing (24) by GDP, which is given by $\left(1 + \frac{1-\lambda}{\lambda} a_X(a)\right) AK^{\alpha}$ along a Markov-perfect equilibrium.

The result in the Proposition above implies the existence of a continuous multiplicity of (expectation-driven) Markov-perfect equilibria. Whatever expectation the government may have on household consumption, i.e. whatever the value for a assumed by the government, it will become self-fulfilled by the policies set under those expectations. Hence, any value of $a \in (0, 1)$ that renders economic variables within their feasible ranges conforms a Markov-perfect equilibrium, with policy functions as given in the Proposition. In addition to these equilibria where a remains constant along the equilibrium path, equilibria with time-varying levels of a can also be constructed. In this latter type of equilibria, a shock to expectations changes the level of a to a new value until it is hit again by a new shock.[2] These are the equilibria we will look at in this paper. Furthermore, we will assume that shocks to expectations are unanticipated, in the sense that every time expectations change agents assume they will remain unchanged thereafter.

More specifically, we use U.S. data on household consumption expenditure as a share of GDP from 1960 to 2010 to construct a sequence $\{a_t\}$. With this sequence we generate optimal income tax rates and optimal government expenditures as a share of GDP from equations (25) and (26). This optimal fiscal policy is then compared to U.S. fiscal policy from 1960 to 2010. The next section constructs the fiscal policy variables in the U.S. economy.

III. U.S. Taxation and Government Expenditure from 1960 to 2010

We use data from the U.S. Bureau of Economic Analysis' NIPA Tables to construct fiscal policy variables for the period $1960 - 2010$. As pointed out by Edward C. Prescott (2004), when using models where the households pay all the taxes, national income accounts must be adjusted to render measured variables consistent with the model variables. The first adjustment calls for the removal of *Taxes on Production and Imports* (TPI) net of *Subsidies to Production* (SUB) from *Gross Domestic Product* (GDP). Both TPI and SUB are available from NIPA Tables 3.5 and 3.13, respectively. The resulting adjusted value of GDP corresponds to output in the model ($Y \equiv C + G + pK'$). That is

$$Y = GDP - (TPI - SUB). \tag{27}$$

Since TPI includes consumption and investment taxes as well as property taxes, the adjustment of the components of GDP by expense (consumption, investment and government expenditure) is as follows. Private consumption expenditure is adjusted by net taxes on consumption and by a fraction of property taxes. Similarly, investment expenditure is adjusted by net taxes on investment and by a fraction of property taxes. Finally, government consumption expenditure is

[2]There is a strand of the business cycle literature studying models that display equilibrium indeterminacy, where fluctuations in economic variables are then generated by randomizations over the set of certainty equilibria (see, for example, Jess Benhabib and Roger E. A. Farmer 1994).

adjusted by a fraction of property taxes. The fraction of the property taxes deducted from each component equals the contribution of the component to GDP gross of the property taxes.

A. *Consumption and Investment Tax Rates*

Our construction of the tax rates on consumption and investment follows closely Cara E. McDaniel (2011), who builds on Prescott (2004). The two starting aggregates to pin down consumption and investment tax rates are *Taxes on Production and Imports* (TPI) and *Subsidies to Production* (SUB). As explained above, besides consumption and investment taxes, TPI also includes property taxes paid both by households and by other entities. Since property taxes paid by households are mostly taxes on owner occupied housing services, these taxes can be thought of as consumption taxes. However, property taxes paid by other entities are removed from TPI to obtain $\overline{TPI}$, so that taxes paid on consumption and investment, net of subsidies, amount to $\overline{TPI} - SUB$. To split this total between taxes on consumption and taxes on investment, Prescott (2004) assumes that two-thirds fall directly on private consumption expenditures, C, and that the remaining one-third is distributed evenly over private consumption and private investment, $C + I$. McDaniel (2011), instead, identifies taxes that fall strictly on consumption expenditures and lowers the two-thirds assumed by Prescott (2004) to 0.506, which yields net taxes paid on consumption, say TPI_c, as

$$TPI_c = \left(0.506 + 0.494\frac{C}{C+I}\right)(\overline{TPI} - SUB),$$

where both C and I are gross of taxes, as reported in the national accounts. Tax rates on consumption are hence constructed as

$$\tau_c = \frac{TPI_c}{C - TPI_c}. \tag{28}$$

Figure 1 presents the so constructed consumption tax rates for the U.S. from 1960 to 2010.

[Insert Figure 1 around here]

Tax rates on investment are constructed as

$$\tau_x = \frac{TPI_x}{I - TPI_x}, \tag{29}$$

where TPI_x is revenue from investment taxes, which is given by $TPI_x = \overline{TPI} - SUB - TPI_c$. Figure 2 presents the so constructed tax rates on investment from 1960 to 2010.

[Insert Figure 2 around here]

B. *Income Tax Rates*

We now construct the empirical counterpart of the income tax rate in our model economy. Since in our model *all* taxes are paid by the households, our construction of the income tax rate includes: (i) *Personal Current Taxes*, PCT, (taxes paid by persons on income); (ii) *Taxes on Corporate Income,* TCI, (taxes paid by firms on income); and (iii) *Contributions for Government Social Insurance,* CSI, (employers contributions for government social insurance as well as payments by employees). These tax aggregates are available from NIPA Table 3.10. We construct income tax rates by dividing the sum of these three tax aggregates by total household income, that is

$$\tau = \frac{PCT + TCI + CSI}{GDP - (TPI - SUB)}. \tag{30}$$

It should be noted that by adding up these three tax aggregates, which actually have different tax bases, we are constructing synthetic direct tax rates in terms of total income. Figure 3 presents the so constructed income tax rates for the U.S. economy from 1960 to 2010.

[Insert Figure 3 around here]

C. *Government Expenditure in Public Goods and Services*

As expenditures in public goods and services, we consider expenditures incurred by the general government on both individual consumption goods and services and collective consumption services. Individual consumption goods and services include education, healthcare, recreation and culture, etc. Collective consumption services include national defense and public order and safety (police, fire, law courts and prisons). Expenditures in these two categories of goods and services appear in NIPA Table 3.9.5 as *Government Consumption Expenditures.* Figure 4 below plots government consumption expenditures (GCE) as a share of gross domestic product, constructed as

$$g = \frac{GCE}{GDP - (\overline{TPI} - SUB)}, \tag{31}$$

so that it is consistent with government consumption expenditures as a share of GDP of the model. Note that the denominator in (31) is not $(TPI - SUB)-$adjusted GDP, since we have

$\overline{TPI}$ instead of TPI, the difference between the two being property taxes paid by entities other than households. By writing g this way we are removing a fraction of these property taxes from GCE, as we will do from all other components of GDP. As explained above, the fraction deducted from each component is the contribution of the component to GDP gross of the properties taxes.

[**Insert Figure 4 around here**]

IV. Markov-perfect Optimal Policy versus U.S. Policy

In this section we use our model economy to generate optimal income tax rates and government consumption expenditure-to-DGP ratios and compare them with their empirical counterparts constructed above. We start by calibrating the parameters of our model so that it matches the average values of key variables of the U.S. economy.

A. *Calibration*

We calibrate the model economy using annual U.S. data from 1960 to 2010. There are six parameters in our model: A, λ, D, β, α and θ. Since there is a multiplicity of Markov-perfect equilibria, which yields a family of equilibrium policy functions indexed by $a \in (0,1)$, we must also set the value of a, along with the parameters of the model. The six parameter values and the value of a are pinned down so that the steady-state of the Markov-perfect equilibrium matches a set of average values for the U.S. economy in the period 1960-2010. The value of A is set equal to one. To set the value of λ we use the restrictions in (7), which yield the equivalence between our capital production technology, (2), and the standard law of motion for capital under quadratic adjustment costs, (6). Therefore, the value of λ is set equal to 0.08, which is the annual depreciation rate of capital. The value of parameter D is obtained directly from the value of λ using (7) as $\lambda^{-\lambda}$. The value of β is set at 0.95, which is the standard value for the annual discount factor used in the macro literature and matches a rate of return on capital of 5.3%. The two remaining parameters, α and θ, and the value of a are set to match the following three targets: (i) An average labor's share of income equal to 0.6136; (ii) An average ratio of investment to gross domestic product of 0.2765, which is the ratio obtained from adding up private and public investment, household consumption in durable goods and net exports, and then dividing by adjusted GDP. By considering net exports as investment, we follow Edward C. Prescott and Ellen R. McGrattan (2010); (iii) An average ratio of household consumption in non-durable goods and services to gross domestic product of 0.5591. More explicitly, α, θ and a are the solution to the following system of three equations

$$\frac{1-\alpha}{1+\frac{1-\lambda}{\lambda}a_X(a)} = 0.6136 \tag{32}$$

$$\frac{a_X(a)}{\lambda+(1-\lambda)a_X(a)} = 0.2765 \tag{33}$$

$$\frac{a}{1+\frac{1-\lambda}{\lambda}a_X(a)} = 0.5591, \tag{34}$$

where, as indicated above, the function $a_X(a)$ is shown in the Appendix.

Table 1 presents our baseline economy.

TABLE 1—BASELINE ECONOMY

Parameter	Value	Target
A	1	normalization
λ	0.0800	capital depreciation rate of 8%
D	1.1954	$\lambda^{-\lambda}$
β	0.9500	rate of return on capital of 5.3%
α	0.1700	labor share of income of 0.6136
θ	6.9787	investment-to-output ratio of 0.2765
a	0.7348	household consumption-to-output ratio of 0.5591

It should be noted from our calibration procedure that the value set for a implies that the average U.S. government consumption expenditure-to-GDP ratio between 1960 and 2010 is also matched. In the next subsection we drop this value of a and construct equilibrium paths for Markov-perfect optimal policy from (25) and (26).

B. *Non-stationary Expectations and Equilibrium Selection*

We now focus our attention on equilibrium paths with time-varying values of a. The multiplicity of Markov-perfect equilibria shown in Proposition 1 opens a channel for expectations to determine the equilibrium path, and raises the issue of equilibrium selection so that the model's policy prescriptions can be compared to U.S. policy. Selecting an equilibrium path in our model ultimately amounts to pinning down a sequence $\{a_t\}$, which can then be used to generate income tax rates and government consumption expenditures as a share of GDP from (25) and (26). Our approach uses the annual household consumption-to-GDP ratios in the U.S. between 1960-2010, along with the parameter values set above, to construct a sequence $\{a_t\}$ so that the equilibrium path of our model matches this ratio year by year. It should be emphasized that we are using information only on household consumption and GDP, but neither information on income tax rates nor on government consumption expenditure is being used to pin down the sequence $\{a_t\}$. We will elaborate more on this below. The procedure described above amounts to solving the following system of 51 equations in the 51 unknowns $\{a_t\}_{t=1960}^{2010}$

$$\frac{a_t}{1+\frac{1-\lambda}{\lambda}a_X(a_t)} = \frac{C_t^{US} - TPI_c}{GDP_t^{US} - (\overline{TPI} - SUB)}, \tag{35}$$

where C_t^{US} denotes U.S. household consumption expenditure in non-durable goods and services and GDP_t^{US} denotes U.S. gross domestic product. Again, note that the denominator is not $(TPI - SUB)-$adjusted GDP, because we have to adjust household consumption expenditure not only by consumption taxes but also by a fraction of the property taxes paid by entities other than households. As we did with government consumption expenditure, this fraction is the contribution of the component to GDP gross of the property taxes.

Once the sequence $\{a_t\}$ has been obtained, we generate optimal income tax rates and government consumption expenditure-to-GDP ratios using the expressions in the Corollary above. For the sake of clarity, we write here these expressions evaluated at the sequence $\{a_t\}$

$$\tau_t = 1 - \frac{(1+\tau_{c,t})(1+\tau_{x,t-1})a_X(a_t)}{\beta(1+\tau_{c,t-1})[\alpha\lambda + (1-\lambda)a_X(a_t)]} \tag{36}$$

and

$$g_t = \frac{a_G(a_t)}{1+\frac{1-\lambda}{\lambda}a_X(a_t)}. \tag{37}$$

C. *Optimal versus U.S. Fiscal Policy*

We now compare Markov-perfect optimal policy with U.S. income tax rates and the U.S. government consumption expenditure-to-GDP ratios for the period 1960-2010. Figure 5 presents optimal income tax rates and U.S. tax rates. Between 1960 and 2001, the two rates follow a similar upward trend and are fairly close to each other. However, from 2001 to 2010 optimal and actual tax rates follow opposite trends, opening a gap between the two rates. While the model prescribes that income taxation should have continued increasing during the decade of the 2000s, U.S. income taxes decreased in the early 2000s and for most of the decade.

[insert Figure 5 around here]

Regarding government consumption expenditure, see Figure 6 below, the U.S. expenditure-GDP ratio also compares well with the optimal ratio until the early 2000s. Again, from 2001 onwards actual and optimal ratios follow opposite trends. While the optimal ratio continues to decline, the U.S. ratio initiates a marked increase until 2010. By way of illustration, the U.S. government expenditure-GDP ratio was 14.4% in 2001 and 17.7% in 2010. The optimal ratio prescribed by our model is 15% in 2001 and 13.7% in 2010.

[insert Figure 6 around here]

D. *Discussion*

Our assessment of the optimality of U.S. income tax rates and government consumption expenditures must be interpreted correctly within the context of our exercise. The proposed model economy yields a multiplicity of expectation-driven equilibria, implying that it is not well suited to derive unconditional prescriptions on optimal fiscal policy. However, the model establishes a unique relationship between macroeconomic aggregates and policy variables which we use to obtain optimal tax rates and government consumption expenditures conditional on household consumption. That is, setting the consumption function of the households to match U.S. private consumption, the equilibrium of the model provides the fiscal policy that is optimal given that consumption function. This is exactly our approach to select the equilibrium path that is then compared to actual U.S. fiscal policy. In this sense, the question we answer in this paper is: given the household consumption-to-GDP ratios of the U.S. economy from 1960 to 2010, what are the optimal income tax rates and the optimal government expenditure-to-GDP ratios and how they compare with those of the U.S.? Figures 5 and 6 provide the answer to this question. These figures show that U.S. tax rates and government expenditures track fairly well their optimal levels from 1960 to 2000. However, in the early 2000s actual and optimal policies begin to depart from each other and follow opposite trends until 2010.

It is worth noting that our approach in this paper is useful to assess the optimality of past fiscal policy, but it cannot be used to design future optimal policy. That is, once we know past household consumption-to-GDP ratios, the equilibria of our model informs of the income tax rates and government consumption expenditure-to-GDP ratios that would have been optimal. However, our model is unsuited to prescribe future optimal fiscal policy, since it has a continuous multiplicity of expectation-driven equilibria.

The tax cuts of the 2000s. The *Economic Growth and Tax Relief Reconciliation Act of 2001*

(EGTRRA), approved on May 25, 2001 introduced temporal tax cuts totalling 1.6 trillion dollars. In addition to a series of tax rebates, it introduced sizable reductions (between 3 and 5 percentage points) in individual income tax rates as well as in capital gains taxes. The schedule for income tax reductions started on July 1, 2001, with a phase-down period of five years and an expiration date of ten. The *Jobs and Growth Tax Relief Reconciliation Act of 2003 (JGTRRA)* reduced further capital gains taxes and accelerated the reductions in individual income tax rates that had been scheduled in the EGTRRA. According to the tax rates we constructed in Section 4, the combination of EGTRRA and JGTRRA reduced the income tax rate from 24% in year 2000 to 18.5% in 2010. The bulk of this reduction came from cuts in personal current taxation and in contributions for government social insurance as shares of adjusted GDP. On the contrary, corporate income taxation as a share of adjusted GDP in 2010 was about the same as in 2000 (2.8%).

Since their approval, EGTRRA and JGTRRA have triggered heated debates on the optimality of such tax cuts. A group of academics and the Secretary of the Treasury at the time strongly opposed the cuts, arguing that they would worsen the long-term budget outlook. Others endorsed the cuts but warned that they should be offset with government spending cuts. According to our model, the tax reductions of the early 2000s were non-optimal, given the household consumption-to-GDP ratios at the time.

The spending hikes of the 2000s. U.S. Government consumption expenditure increased from 15% of adjusted GDP in 2000 to 18.7% in 2010. This increase was the result of both federal and state and local increases in consumption expenditure. At the federal level, both defense and non-defense consumption expenditures increased. For example, expenditure in national defense went from 3.2% of adjusted GDP in 2000 to 4.8% in 2010; federal non-defense consumption expenditure went from 1.75% of adjusted GDP to 2.6%. State and local consumption expenditure increased from 10.2% in 2000 to 11.2% in 2010. According to our model, the spending hikes of the 2000s were non-optimal, given household consumption expenditure at the time. Our model prescribes that government consumption expenditure should had been reduced from 15.5% in 2000 to 14.5% in 2010.

VI. Concluding Remarks

This paper provides an assessment of the optimality of U.S. income taxation and government consumption expenditure from 1960 to 2010. The normative theory used to generate optimal policy builds on the public finance literature initiated by Judd (1985) and Chamley (1986).

We relax the assumption of government full commitment to policy and focus our attention on the Markov-perfect equilibria of a model where the government acts sequentially. We find a continuous multiplicity of such equilibria, from which we obtain a unique relationship between optimal fiscal policy and household consumption. By using this relationship and U.S. data on household consumption we can hence generate the fiscal policy that is optimal for those levels of household consumption.

When optimal and actual income tax rates and government consumption expenditure are compared, our model supports the optimality of U.S. fiscal policy only in the period between 1960 and 2000, but not from 2001 to 2010. In this later period, optimal and actual policies follow opposite trends, with actual income tax rates decreasing below their optimal values and government consumption expenditure increasing above the levels prescribed by our model.

APPENDIX

PROOF OF PROPOSITION 1:

Markov-perfect equilibrium policies are derived using a guess-and-verify approach. This approach proceeds in three steps. In the first step, we conjecture parametric forms for the equilibrium consumption function, C, and the continuation value function, $\tilde{V}$, and derive the government's policy function for the provision of the public good, ψ_G. In the second step, we use the government's budget constraint and the policy function ψ_G, together with a no-Ponzi scheme constraint, to derive the policy function $\psi_{B'}$, conditional on the functions conjectured in the first step. Then, we use the household Euler equation, the debt sustainability condition and the restriction that the continuation value function must solve the government Bellman equation [i.e., $V = \tilde{V}$)] to derive the tax policy function, ψ_τ, and the parameters in the conjectured functions C and $\tilde{V}$.

Conjectures. We conjecture that household consumption is of the form $C = aAK^\alpha$, where a is a parameter to be determined. The continuation value for the period-t government is conjectured to be of the form $\tilde{V}(K') = A_1 + A_2 \ln K'$, where A_1 and A_2 are parameters to be determined.

The period-t government's maximization problem. The government chooses fiscal policy for the current period, subject to the resource constraint, to its budget constraint, to the no-arbitrage condition between physical capital and public debt, equation (14), and to the pricing functions for p, r and w.

Plugging the pricing functions into the period-t government's maximization problem under the conjectures above, this problem becomes

$$\max_{B',\tau,G}\{\ln(aAK^{\alpha})+\theta\ln G+\beta(A_1+A_2\ln K')\}$$

$$s.t.$$

$$aAK^{\alpha}+X+G=AK^{\alpha} \tag{38}$$

$$G+T+B=\beta\left(\frac{1+\tau_c}{1+\tau_c'}\frac{K^{\alpha\lambda}}{X^{\alpha\lambda}}\right)B'+\tau\left(AK^{\alpha}+\frac{1-\lambda}{\lambda}X\right)+\tau_c aAK^{\alpha}+\tau_x\frac{X}{\lambda} \tag{39}$$

$$K'=DX^{\lambda}K^{1-\lambda}, \tag{40}$$

where equation (38) is the resource constraint, equation (39) is the government budget constraint, and equation (40) is the production technology in the capital good sector.

The first-order condition of the government maximization problem with respect to expenditure in the public good is

$$\frac{\theta}{G}=\beta A_2\frac{\lambda DX^{\lambda-1}K^{1-\lambda}}{K'}, \tag{41}$$

which, after plugging the value for K' from the capital production technology, it yields

$$\frac{\theta}{G}=\beta A_2\frac{\lambda}{X}. \tag{42}$$

The combination of this first-order condition with the resource constraint, (38), yields the level of government spending in the public good as

$$G=\frac{(1-a)\theta}{\theta+\beta A_2\lambda}AK^{\alpha}. \tag{43}$$

For future reference, we denote the constant multiplying AK^{α} on the right-hand side of this equation as $a_G(a)$, i.e.

$$a_G(a)\equiv\frac{(1-a)\theta}{\theta+\beta A_2\lambda}. \tag{44}$$

The level of household spending in the capital good (savings in the physical asset) is

$$pK'=\frac{(1-a)\beta A_2}{\theta+\beta A_2\lambda}AK^{\alpha}. \tag{45}$$

And the amount of the homogenous good used as an input in the production of the capital good is

$$X=\frac{(1-a)\beta A_2\lambda}{\theta+\beta A_2\lambda}AK^{\alpha}. \tag{46}$$

For future reference, we denote the constant multiplying AK^α on the right-hand side of this equation as $a_X(a)$, i.e.

$$a_X(a) \equiv \frac{(1-a)\beta A_2\lambda}{\theta + \beta A_2 \lambda}. \tag{47}$$

The household Euler equation. Under the consumption function conjectured above the household Euler equation becomes

$$\frac{1}{(1+\tau_c)aAK^\alpha} = \frac{\beta(1-\tau')\lambda D X^{\lambda-1}K^{1-\lambda}}{(1+\tau_c')aAK'^\alpha(1+\tau_x)}\left(\alpha AK'^{\alpha-1} + \frac{(1-\lambda)X'^\lambda K'^{-\lambda}}{\lambda X'^{\lambda-1}K'^{1-\lambda}}\right).$$

After some algebra we get

$$\frac{1}{(1+\tau_c)AK^\alpha} = \frac{\beta(1-\tau')\lambda D X^{\lambda-1}K^{1-\lambda}}{(1+\tau_c')AK'^\alpha(1+\tau_x)}\left(\alpha AK'^{\alpha-1} + \frac{(1-\lambda)}{\lambda}\frac{X'}{K'}\right).$$

Using the capital production technology and the policy function for X, equation (46), we get

$$\frac{1+\tau_x}{1+\tau_c} = \beta\left(\frac{\alpha\lambda}{a_X(a)} + 1 - \lambda\right)\left(\frac{1-\tau'}{1+\tau_c'}\right).$$

We then obtain the tax rate on income in period $t+1$ as

$$\tau' = 1 - \frac{(1+\tau_c')(1+\tau_x)a_X(a)}{\beta(1+\tau_c)[\alpha\lambda + (1-\lambda)a_X(a)]}. \tag{48}$$

Debt sustainability (no-Ponzi condition). We now use the debt sustainability requirement to derive the debt and tax policy functions. For the sake of expositional clarity we will use here time subscripts to date variables. We will return to our previous notation when there is no risk of ambiguity.

The period-$(t+1)$ government budget constraint is

$$G_{t+1} + T_{t+1} + B_{t+1} = q_{t+1}B_{t+2} + \tau_{t+1}\left(w_{t+1} + r_{t+1}K_{t+1}\right) + \tau_{c,t+1}C_{t+1} + \tau_{x,t+1}p_{t+1}K_{t+2}. \tag{49}$$

Using the pricing equations, (3), (4), (5) and (14), the policy function for government expenditure in the public good, (43), and the policy function for the amount of the homogeneous good used as an input into the production of the capital good, (46), this budget constraint becomes

$$\begin{aligned} a_G(a)AK_{t+1}^\alpha + T_{t+1} + B_{t+1} &= \beta\frac{1+\tau_{c,t+1}}{1+\tau_{c,t+2}}\frac{AK_{t+1}^\alpha}{AK_{t+2}^\alpha}B_{t+2} \\ &+ \tau_{t+1}\left(AK_{t+1}^\alpha + \frac{1-\lambda}{\lambda}a_X(a)AK_{t+1}^\alpha\right) + \left(a\tau_{c,t+1} + \frac{a_X(a)}{\lambda}\tau_{x,t+1}\right)AK_{t+1}^\alpha. \end{aligned} \tag{50}$$

As indicated above, transfers to households and tax rates on consumption and investment are assumed to be exogenously given. We write transfers as a fraction, $a_{T,t}$, of production of the homogeneous good, i.e. $T_t = a_{T,t} A K_t^{\alpha}$. Plugging this expression for transfers into the equation above and dividing both sides of this equation by AK_{t+1}^{α} it yields

$$
\begin{aligned}
a_G(a) + a_{T,t+1} + \frac{B_{t+1}}{AK_{t+1}^{\alpha}} &= \beta \frac{1+\tau_{c,t+1}}{1+\tau_{c,t+2}} \frac{B_{t+2}}{AK_{t+2}^{\alpha}} \\
&+ \tau_{t+1}\left(1 + \frac{1-\lambda}{\lambda} a_X\right) + a\tau_{c,t+1} + \frac{a_X(a)}{\lambda}\tau_{x,t+1}.
\end{aligned} \tag{51}
$$

Rearranging, we obtain

$$
\begin{aligned}
\frac{B_{t+2}}{AK_{t+2}^{\alpha}} &= \frac{1}{\beta} \frac{1+\tau_{c,t+2}}{1+\tau_{c,t+1}} \frac{B_{t+1}}{AK_{t+1}^{\alpha}} \\
&+ \left(a_G(a) + a_{T,t+1} - \tau_{t+1}\left(1 + \frac{1-\lambda}{\lambda} a_X\right) - a\tau_{c,t+1} - \frac{a_X(a)}{\lambda}\tau_{x,t+1}\right) \frac{1}{\beta} \frac{1+\tau_{c,t+2}}{1+\tau_{c,t+1}}.
\end{aligned} \tag{52}
$$

Note that τ_{t+1} is given by (48) as a function of $\tau_{c,t}, \tau_{c,t+1}, \tau_{x,t}$ and a (the parameter in the conjectured consumption function). For clarity of exposition, let us introduce the following notation. We denote the term multiplying $\frac{B_{t+1}}{AK_{t+1}^{\alpha}}$ on the right-hand side of equation (52) by h_1, i.e.

$$
h_1 \equiv \frac{1}{\beta} \frac{1+\tau_{c,t+2}}{1+\tau_{c,t+1}}. \tag{53}
$$

The second addend on the right-hand side is denoted by h_2, i.e.,

$$
h_2 \equiv \left(a_G(a) + a_{T,t+1} - \tau_{t+1}\left(1 + \frac{1-\lambda}{\lambda} a_X(a)\right) - a\tau_{c,t+1} - \frac{a_X(a)}{\lambda}\tau_{x,t+1}\right) h_1, \tag{54}
$$

where τ_{t+1} is given by (48). It should be noted that both h_1 and h_2 are hence determined by exogenous variables (transfers and tax rates on consumption and investment).

With this notation, equation (52) is written as

$$
\frac{B_{t+2}}{AK_{t+2}^{\alpha}} = h_1 \frac{B_{t+1}}{AK_{t+1}^{\alpha}} + h_2. \tag{55}
$$

It thus follows that equation (52) is a first-order, non-homogeneous difference equation with variable coefficients in the ratio of public debt to production in the sector of the consumption good. For convenience, we assume that the exogenous sequences $\{\tau_{c,t}, \tau_{x,t}, a_{T,t}\}$ converge to constant values in the long run. A consequence of this assumption is that $\frac{1+\tau_{c,t+2}}{1+\tau_{c,t+1}} = 1$ in the long run and that there is a steady-state value of $\frac{B}{AK^{\alpha}}$. It is straightforward to see from (52) that this steady-state value is not asymptotically stable, as $\beta < 1$. We derive the Markov-perfect debt policy function by imposing debt sustainability. That is, the government in period t (and then all subsequent governments) will set debt issues, B_{t+1}, so that it successor will set, under the Markov-perfect policies for expenditure and income taxation, the same debt issues as a fraction of production of the consumption good. That is,

$$B_{t+1} = \left(\frac{h_2}{1-h_1}\right) AK_{t+1}^{\alpha}, \tag{56}$$

which, after using the technology in the capital sector and the policy function (46), we obtain the debt policy function of the period-t government, which we write using our notation in the text as

$$\psi_{B'}(K;a) = \left(\frac{h_2}{1-h_1}\right) \left(Da_X(a)^{\lambda}\right)^{\alpha} A^{1+\alpha\lambda} K^{(1-(1-\alpha)\lambda)\alpha}. \tag{57}$$

We denote $h_2/(1-h_1)$ by h.

We now derive the policy function for income taxation, ψ_τ. This is obtained from the budget constraint of the period-t government

$$G_t + T_t + B_t = q_t B_{t+1} + \tau_t \left(w_t + r_t K_t\right) + \tau_{c,t} C_t + \tau_{x,t} p_t K_{t+1}. \tag{58}$$

Plugging into this budget constraint the conjectured policy function for consumption, the policy functions for government spending in the public good, (57), the policy function for the amount of the homogeneous good used as an input in the capital sector, (57), and the pricing equations we obtain

$$\begin{aligned} a_G(a)AK_t^{\alpha} + T_t + B_t \;&=\; \beta \frac{1+\tau_{c,t}}{1+\tau_{c,t+1}} \frac{AK_t^{\alpha}}{AK_{t+1}^{\alpha}} B_{t+1} \\ &+\; \tau_t \left(AK_t^{\alpha} + \frac{1-\lambda}{\lambda} a_X(a) AK_t^{\alpha}\right) + \left(a\tau_{c,t} + \frac{a_X(a)}{\lambda}\tau_{x,t}\right) AK_t^{\alpha}. \end{aligned} \tag{59}$$

Dividing both sides of this equation by AK_t^{α}, using the debt policy function (57) and rearranging yields the tax policy function as

$$\psi_\tau(K,B;a) = \frac{B}{\left(1+\frac{1-\lambda}{\lambda}a_X(a)\right) AK^{\alpha}} + f, \tag{60}$$

where f is a function of a, of the exogenous tax rates on consumption and investment and of the exogenous transfers to households, and is given by

$$f \equiv \frac{a_G(a) + a_T - a\tau_c - \frac{a_X(a)}{\lambda}\tau_x - \beta \frac{1+\tau_c}{1+\tau_c'} \frac{h_2}{1-h_1}}{1+\frac{1-\lambda}{\lambda}a_X(a)}.$$

The conjectured continuation value $\tilde{V}$ solves the government's Bellman equation. We now obtain the parameters in the conjectured value function, $\tilde{V}$, so that it solves the Bellman equation of the government. That is

$$A_1 + A_2 \ln K = \ln(aAK^{\alpha}) + \theta \ln G + \beta \left(A_1 + A_2 \ln K'\right),$$

where G and K' are the values obtained above under the conjectures. After plugging the values of G and K' we get

$$A_1 + A_2 \ln K \quad = \quad \ln(aAK^\alpha) + \theta \ln(a_G(a)AK^\alpha) + \beta A_1 + A_2 \ln\left((a_X(a)AK^\alpha)^\lambda K^{1-\lambda}\right).$$

From this equation we solve for A_1 and A_2 and obtain

$$A_1 = \frac{\ln a + (1+\theta)\ln A + \theta \ln a_G(a) + \beta A_2 \lambda(\ln a_X(a) + \ln A)}{1-\beta} \tag{61}$$

$$A_2 = \frac{(1+\theta)\alpha}{1-\beta(1-(1-\alpha)\lambda)}. \tag{62}$$

Once A_1 and A_2 have been determined, notice that we can not uniquely pin down a value for a. Any value of a that yields endogenous variables within their feasible ranges conforms a Markov-perfect equilibrium. This equilibrium multiplicy stemms from the fact that public debt is not households' net wealth and hence the government is indifferent between tax and debt financing.

REFERENCES

Abel, Andrew. 2003. "The Effects of a Baby Boom on Stock Prices and Capital Accumulation in the Presence of Social Security." *Econometrica,* 71(2): 551–578.

Benhabib, Jess, and Roger E. A. Farmer. (1994). "Indeterminacy and Increasing Returns." *Journal of Economic Theory,* 63(1): 19–41.

Chamley, Christophe. 1986. "Optimal Taxation of Capital Income in General Equilibrium with Infinite Lives." *Econometrica*, 54(3): 607–622.

Hercowitz, Zvi, and Michael Sampson. (1991). "Output Growth, the Real Wage, and Employment Fluctuations", *American Economic Review,* 81(5): 1215–1237.

Jin, Keyu. (2012). "Industrial Structure and Capital Flows." *American Economic Review,* 102(5): 2111–2146.

Judd, Kenneth L. 1985. "Redistributive Taxation in a Simple Perfect Foresight Model." *Journal of Public Economics,* 28: 59–83.

Klein, Paul, Per Krusell, and José V. Ríos-Rull. (2008). "Time-Consistent Public Policy." *Review of Economic Studies,* vol. 75, pp. 789–808.

Lucas, Robert E., and Edward C. Prescott. (1971). "Investment under Uncertainty." *Econometrica*, 39(5): 659–81.

McDaniel, Cara E. (2007). "Average Tax Rates on Consumption and Investment Expenditures and Labor and Capital Income in the OECD." Manuscript, Arizona State University.

Martin, Fernando M. (2009). "A Positive Theory of Government Debt." *Review of Economic Dynamics,* 12(4): 608–631.

McGrattan, Ellen R., and Edward C. Prescott. 2010. "Unmeasured Investment and the Puzzling U.S. Boom in the 1990s." *American Economic Journal: Macroeconomics,* 2(4): 88–123.

Ortigueira, Salvador. 2006. "Markov-perfect optimal Taxation." *Review of Economic Dynamics,* 9(1): 153–178.

Prescott, Edward C. 2004. "Why Do Americans Work so Much More than Europeans?" *Quarterly Review of the Federal Reserve Bank of Minneapolis,* (July), 2–13.

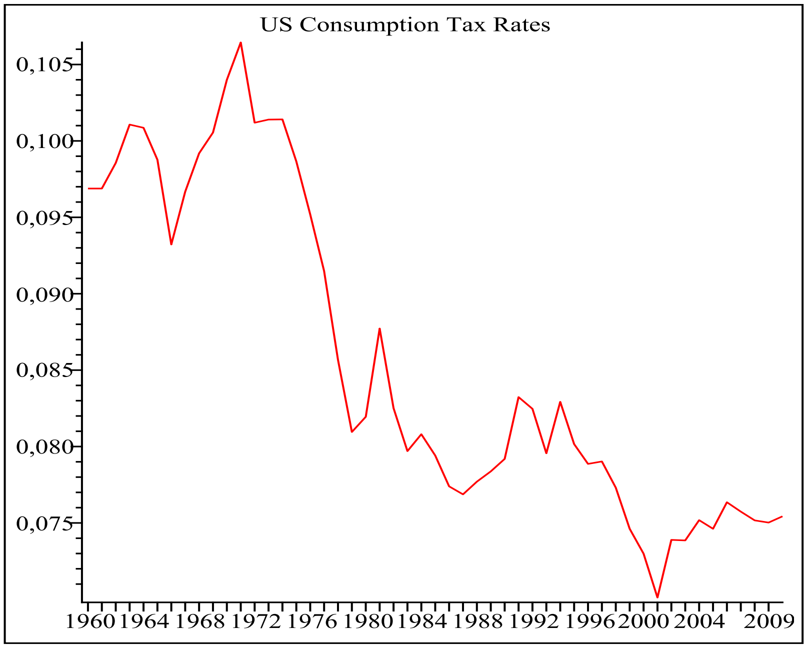

FIGURE 1. U.S. CONSUMPTION TAX RATES, 1960-2010.

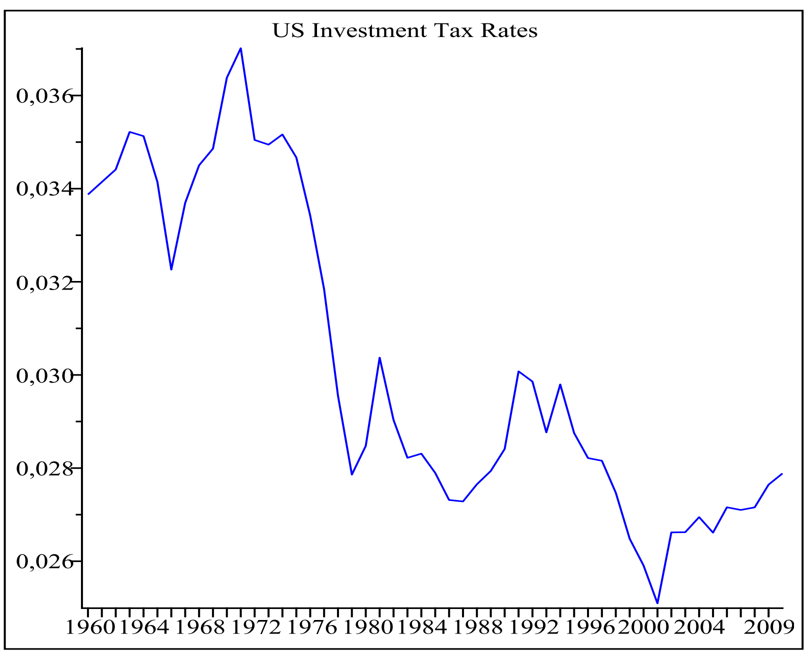

FIGURE 2. U.S. INVESTMENT TAX RATES, 1960-2010.

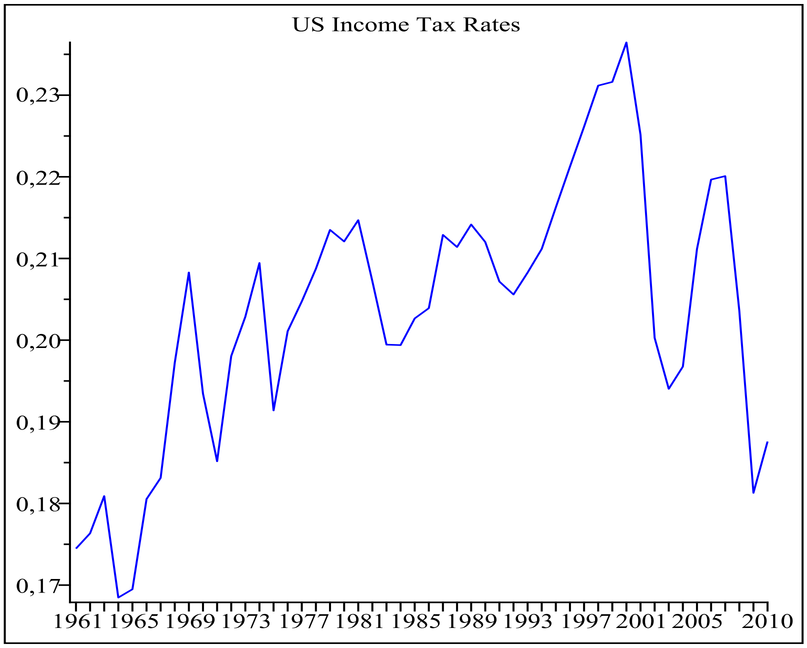

FIGURE 3. U.S. INCOME TAX RATES, 1960-2010.

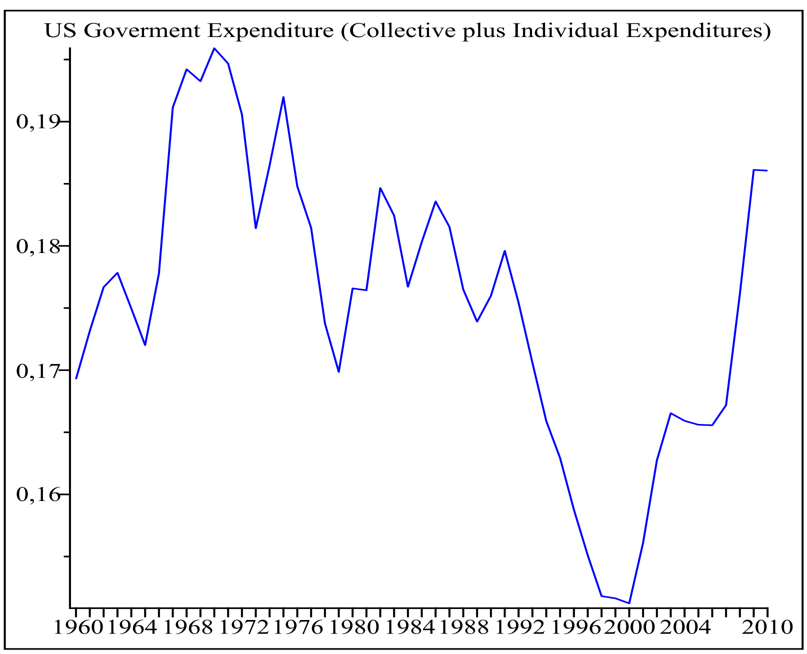

FIGURE 4. U.S. GOVERNMENT CONSUMPTION EXPENDITURE, 1960-2010.

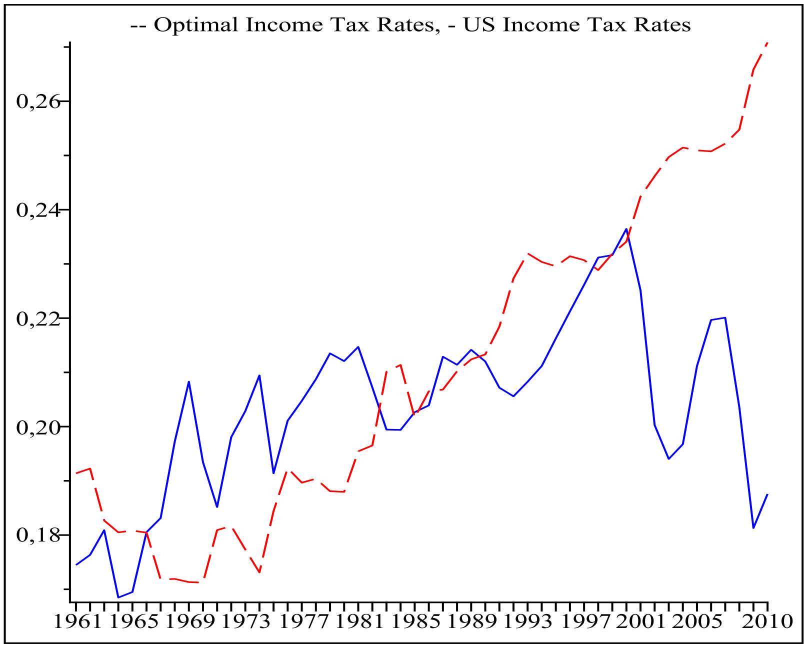

FIGURE 5. OPTIMAL VERSUS U.S. INCOME TAX RATES, 1961-2010.

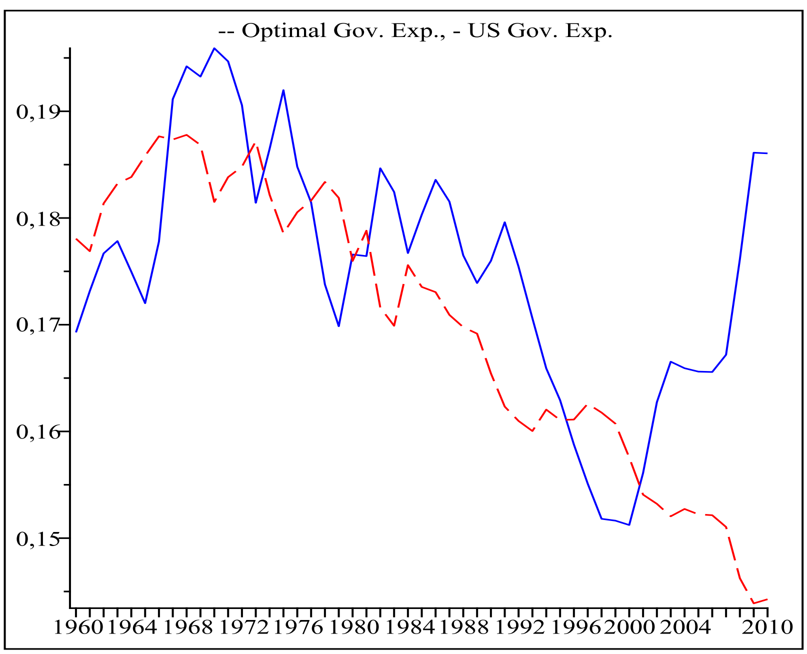

FIGURE 6. OPTIMAL VERSUS U.S. GOVERNMENT EXPENDITURE, 1960-2010.